

ATTACHMENT 2

Comparison of Depth-Duration-Frequency Curves Obtained from NOAA14 and Estimated from MM5 Simulated Precipitation

LAKE TAHOE BASIN, CALIFORNIA AND NEVADA

Prepared for:



Prepared by:



**US Army Corps
of Engineers®**

Sacramento District

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Executive Summary

- 1) The purpose of this document is to describe comparison of precipitation depth-duration-frequency (DDF) curves estimated for Lake Tahoe Basin from precipitation simulated by the MM5 atmospheric model and the estimates recently published by the National Weather Service in NOAA14.
- 2) The comparison being performed by the Sacramento District Corps of Engineers was requested by the Storm Water Quality Investigation Committee (SWQIC) of the Lake Tahoe Basin.
- 3) The MM5 simulated precipitation is being used by the State of California Lahontan Regional Water Quality Control Board (LRWQCB) and Nevada Division of Environmental Protection (NDEP) as part of a modeling study to understand impacts on the water quality of the Lake Tahoe Basin. **It is important to note that no claim has been made by the LRWQCB that the simulated precipitation should be used for estimating precipitation DDF curves.** Rather, the SWQIC has requested this investigation to assess what are the potential differences between NOAA14 and any potential future application of the MM5 simulated precipitation to obtain DDF curves.
- 4) The simulated data compared generally well with annual daily maximum observed gage precipitation over the recorded period of record, except where there is significantly higher predictions for elevations between 6500-7500 feet. This difference could certainly be due to the following factors: 1) differences in period of record; 2) the limited coverage provided by the precipitation gages; 3) MM5 provides grid cell average amounts and gage information is essentially a point estimate; and, 4) MM5 model error versus gage catch errors.
- 5) The DDF distributions were inferred from the hourly precipitation simulations at 142 3kmx3km grid cells covering the Lake Tahoe basins using L-moment estimation techniques. The results of the analysis demonstrated that the generalized logistic distribution did an adequate job in describing the simulated MM5 precipitation for 1hour, 24hour, 7day and 30day durations.
- 6) DDF estimates obtained from MM5 simulated data generally resulted in smaller predictions of precipitation for the 50% (2year) and 10% (10 year) DDF estimates for all durations investigated; but tended to larger predictions for the 1% (100 year) DDF estimates. The closest comparison occurred for the 1% 1hour estimates. Differences did not appear to be a function of MM5 grid elevation.
- 7) DDF estimates obtained from MM5 simulated precipitation generally lied outside the confidence limits provided for NOAA14 DDF estimates. Although not a completely rigorous statistical test, this result indicates that the differences between the estimates is not solely due to statistical sampling error.

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1. Introduction

The purpose of this report is to provide a comparison between depth-duration frequency estimates for Lake Tahoe Basin obtained from the MM5 atmospheric model simulations (NCAR, Roberts) and those published by the National Weather Service in NOAA14 (NWS, 2004, and Bonin, 2004 personal communication). This comparative study is being made by the Sacramento District Corps of Engineers per request of the Storm Water Quality Investigation Committee (SWQIC) for Lake Tahoe Basin. In making this comparison, the application to estimating depth-duration-frequency curves is beyond the intended application of the MM5 simulated precipitation. The Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection is using the simulated data in water quality modeling studies for Lake Tahoe Basin (Roberts, personal communication, 2004). The Lahontan Regional Water Quality Control Board is California State Agency. No study, or claim has been made that this simulated data should be used to estimate depth-duration-frequency curves. Rather, this study is being done at the request of the SWQIC to assess the differences exist between NOAA14 and any potential future use of the MM5 simulated data.

MM5 is a three-dimensional, physically based atmospheric model that was used to simulate period of record conditions from 1958-1999. Depth-duration-frequency estimates for the MM5 simulated data was performed using the same techniques used by the National Weather Service (see Hosking and Wallis, 1997). These estimates were compared to both those published for NOAA14 and unpublished results obtained per special request from the NWS (the published results did not cover the entire Lake Tahoe Basin).

In section 2, a description is provided of the MM5 simulated data and the resulting depth-duration-frequency (DDF) curves estimated from the data. A brief summary of the derivation of the NOAA14 estimated DDF relationships for Lake Tahoe Basin is given in section 3. The comparison of DDF estimates is given in section 4. Appendix information in section 5 provides tables on maximum simulated and observed precipitation for the Lake Tahoe Basin and surrounding area. Appendix information in section 6 provides graphical comparison of estimated distribution (frequency curve) with plotting positions of annual maximum values obtained from the MM5 simulations.

2. MM5 estimates

2.1. Introduction

The purpose of this section is to describe the characteristics of the MM5 simulated precipitation, how it corresponds to gage recorded data, and the inference of annual maximum depth duration frequency characteristics corresponding to the simulated precipitation. Section 2.2 provides a description of the data provided for studying the MM5 simulations. A comparison between the simulated data and precipitation gage observations is provided in section 2.3. Section 2.4, describes the inference of depth-duration-frequency curves from the simulated precipitation.

2.2. Simulated precipitation description

The MM5 simulated precipitation was provided at approximately hourly (i.e., the data was provided in irregular increments of nearly an hour in duration) grid cell area average estimates. The 3kmx3km grid cells covering the Lake Tahoe basin are given in Table 2.1 and relative locations shown in figure 2.1. Annual maximum values for various durations were obtained for each grid cell for the period of record.

2.3. Comparison with observed maximum daily data

A comparison was made between the maximum period of record gage measured precipitation depths and MM5 simulated data. Table 2.2 displays the annual maximum recorded values found for SNOTEL gages in the Lake Tahoe basin study area. Figures 2.2-2.4 compare the maximum values recorded with those found from the period of record MM5 simulated values. As can be seen, the observed and simulated values compare well except between elevation 6000-7500 feet, where MM5 simulations result in significantly greater values. This difference could certainly be due to the following factors: 1) differences in period of record; 2) the limited coverage provided by the precipitation gages; 3) MM5 provides grid cell average amounts and gage information is essentially a point estimate; and 4) MM5 model error versus gage catch errors.

2.4. Estimating depth-duration-frequency distributions

2.4.1. Application of the regional L-moment procedure

The National Weather Service applied the regional L-moment procedure (see Hosking and Wallis, 1997) to estimate precipitation depth-duration-frequency (DDF) distributions described in NOAA14. A similar approach was used in deriving distributions for the MM5 simulated data.

The regional procedure follows these basic steps to obtain a regional DDF distribution:

- 1) Aggregate gages to form an initial region based on similar topographic and meteorologic characteristics;
- 2) Identify unusual data sets by applying a statistic measuring discordancy; reformulate regions to include data that is not discordant;
- 3) Test the aggregation of regional gages using a statistical measure of homogeneity, reformulate region as necessary to obtain homogeneity;

- 4) Identify likely candidate probability distributions that describe the data using a regional goodness of fit measure.

Identifying a homogeneous region is required for identifying a dimensionless frequency curve, referred to as a growth curve, for application within a region. This growth curve can then be used to compute the DDF curves at any location from mapped values of a scaling factor, typically the mean or median precipitation for a particular duration.;

This procedure was not followed exactly because the goal was to identify reasonable distributions for the simulated area average data at each MM5 grid cell, rather than find a regional distribution that could be used at any location within the Lake Tahoe Basin. However, the discordancy, homogeneity and goodness-of-fit statistic were used to ascertain which candidate probability distributions were useful for describing the MM5 data.

The candidate distributions investigated were (see Hosking and Wallis, 1997): 1) generalized logistic (GLO), 2) generalized extreme value (GEV), 3) generalized normal (GNO), 4) Pearson type III (PIII), and 5) Pareto (PTO). These are the same three parameter candidate distributions investigated by the National Weather Service for NOAA14. These distributions were estimated for the annual maximum 1 hour, 1day, 7day and 30 day durations obtained from an analysis of the simulated precipitation data.

The results of the analysis indicated the following:

- 1) The grid cells would need to be divided into zones spanning elevation ranges of about 600 feet and divided by locations east and west locations of the 120° longitude to form homogenous regions;
- 2) GLO, GEV and GNO are acceptable distributions for describing the annual maximums of the simulated MM5 precipitation as measured by the goodness-of-fit statistic.

Perhaps the most interesting aspect of this result is that multiple regions are needed for the Lake Tahoe region. This region detail could not be identified in the NOAA14 study because of lack of gage information.

2.4.2. Final distribution estimates

General experience has shown that most three parameter distributions describe annual maximums very well for the central portion of the distribution, but there is disagreement at the extremes. Consequently, the final distribution was selected based on which distribution best fit the top ranked simulated maximum for each precipitation duration investigated. To make this comparison, the fraction difference between the maximum ranked precipitation for a duration and the corresponding estimated precipitation distribution quantile (e.g., the precipitation for an exceedance probability) for all 142 grid cells was computed. Here the exceedance probability for the maximum ranked value was computed using the median plotting position formula. The distribution quantile is then computed at the plotting position for the corresponding cell maximum precipitation. Since the period of record is the same for all quantiles, the plotting position for the top ranked annual maximum precipitation is the same for all grid cells. The distribution that had the smallest average fractional error over all the grids was presumed to be best for application to MM5 for the purposes of comparison with NOAA14 DDF estimates. Table 2.3 shows that the GLO distribution was marginally better than GEV or GNO.

Interestingly, these are the same distributions identified as acceptable candidate distributions by the goodness-of-fit statistic in the previous section.

The overall fit of the GLO distribution for all durations is excellent as can be seen from the example plots shown in the Section 6 appendix. However, as can be seen from Table 2.3, there is a bias towards under-predicting the top ranked annual maximum precipitation for all durations. Figures 2.5 -2.6 provide examples of this under-prediction as a function of grid cell elevation for the GLO distribution.

Table 2.1: MM5 centroid latitude, longitude, elevation (feet msl) to centroid of 3kmx3km grid cells

grid	lat	long	elev	grid	lat	long	elev	grid	lat	long	elev
1	38.6947	-120.0000	8197	51	38.9445	-120.0000	6267	101	39.1388	-119.9642	6349
2	38.7225	-120.0356	7995	52	38.9445	-119.9643	6547	102	39.1388	-119.9284	6990
3	38.7225	-120.0000	8105	53	38.9445	-119.9286	7655	103	39.1388	-119.8926	7640
4	38.7502	-120.0356	8028	54	38.9444	-119.8929	7741	104	39.1664	-120.2149	7129
5	38.7502	-120.0000	8116	55	38.9721	-120.1785	7836	105	39.1664	-120.1791	6787
6	38.7502	-119.9644	7987	56	38.9721	-120.1428	8026	106	39.1665	-120.1433	6419
7	38.7780	-120.0356	7884	57	38.9722	-120.1071	7055	107	39.1666	-119.9284	6984
8	38.7780	-120.0000	7932	58	38.9722	-120.0714	6311	108	39.1665	-119.8925	7998
9	38.7780	-119.9644	7922	59	38.9722	-119.9643	6329	109	39.1942	-120.1792	6915
10	38.7779	-119.9288	7702	60	38.9722	-119.9286	6960	110	39.1943	-120.1433	6762
11	38.8057	-120.0356	7609	61	38.9722	-119.8929	7231	111	39.1943	-120.1075	6411
12	38.8057	-120.0000	7769	62	38.9998	-120.2143	7180	112	39.1943	-120.0717	6245
13	38.8057	-119.9644	8197	63	38.9998	-120.1786	7636	113	39.1943	-119.9283	6981
14	38.8057	-119.9288	8035	64	38.9999	-120.1429	7513	114	39.1943	-119.8925	7822
15	38.8334	-120.1069	7741	65	38.9999	-120.1072	6726	115	39.2220	-120.1792	7063
16	38.8334	-120.0713	7617	66	39.0000	-119.9643	6356	116	39.2220	-120.1434	7293
17	38.8335	-120.0356	7147	67	39.0000	-119.9286	6972	117	39.2221	-120.1075	6813
18	38.8335	-120.0000	7482	68	38.9999	-119.8928	7310	118	39.2221	-120.0717	6345
19	38.8335	-119.9644	8308	69	39.0275	-120.2144	7231	119	39.2221	-120.0359	6262
20	38.8334	-119.9287	8661	70	39.0276	-120.1787	7223	120	39.2221	-120.0000	6268
21	38.8334	-119.8931	8825	71	39.0277	-120.1430	6772	121	39.2221	-119.9283	6917
22	38.8611	-120.1426	8276	72	39.0277	-120.1072	6343	122	39.2221	-119.8925	7350
23	38.8612	-120.1069	7933	73	39.0278	-119.9643	6388	123	39.2498	-120.1435	7388
24	38.8612	-120.0713	7393	74	39.0277	-119.9285	7199	124	39.2498	-120.1076	7112
25	38.8612	-120.0356	6740	75	39.0277	-119.8928	7690	125	39.2499	-120.0717	6736
26	38.8612	-120.0000	6804	76	39.0553	-120.2145	7525	126	39.2499	-120.0359	6657
27	38.8612	-119.9644	7597	77	39.0554	-120.1788	7172	127	39.2499	-120.0000	6680
28	38.8612	-119.9287	8670	78	39.0554	-120.1430	6505	128	39.2499	-119.9641	6567
29	38.8612	-119.8931	9242	79	39.0555	-120.1073	6260	129	39.2499	-119.9283	7019
30	38.8889	-120.1426	8379	80	39.0555	-119.9642	6411	130	39.2498	-119.8924	7074
31	38.8889	-120.1070	7873	81	39.0555	-119.9285	7287	131	39.2776	-120.0718	7120
32	38.8890	-120.0713	7050	82	39.0555	-119.8927	7917	132	39.2777	-120.0359	7529
33	38.8890	-120.0357	6543	83	39.0830	-120.2504	7353	133	39.2777	-120.0000	7827
34	38.8890	-120.0000	6463	84	39.0831	-120.2146	7492	134	39.2777	-119.9641	7688
35	38.8890	-119.9643	6992	85	39.0831	-120.1788	7016	135	39.2776	-119.9282	7767
36	38.8890	-119.9287	8116	86	39.0832	-120.1431	6381	136	39.2776	-119.8924	7479
37	38.8889	-119.8930	8617	87	39.0833	-119.9642	6362	137	39.3055	-120.0359	7679
38	38.9166	-120.1784	8260	88	39.0833	-119.9285	7029	138	39.3055	-120.0000	8340
39	38.9166	-120.1427	8408	89	39.0832	-119.8927	7452	139	39.3055	-119.9641	8721
40	38.9167	-120.1070	7828	90	39.1108	-120.2505	7328	140	39.3054	-119.9282	8739
41	38.9167	-120.0714	6842	91	39.1108	-120.2147	7319	141	39.3054	-119.8923	8132
42	38.9167	-120.0357	6450	92	39.1109	-120.1789	6760	142	39.3332	-119.9282	9182
43	38.9167	-120.0000	6366	93	39.1110	-120.1431	6289				
44	38.9167	-119.9643	6709	94	39.1110	-119.9642	6370				
45	38.9167	-119.9286	7889	95	39.1110	-119.9284	6901				
46	38.9167	-119.8930	8048	96	39.1110	-119.8926	7158				
47	38.9444	-120.1428	8028	97	39.1385	-120.2506	7309				
48	38.9444	-120.1071	7228	98	39.1386	-120.2148	7317				
49	38.9445	-120.0714	6455	99	39.1387	-120.1790	6755				
50	38.9445	-120.0357	6290	100	39.1387	-120.1432	6314				

									142		
									140	141	
				131	132	133	134	135	136		
		0	123	124	125	126	127	128	129	130	
		115	116	117	118	119	120		121	122	
		109	110	111	112				113	114	
	104	105	106						107	108	
97	98	99	100					101	102	103	
90	91	92	93					94	95	96	
83	84	85	86					87	88	89	
	76	77	78	79				80	81	82	
	69	70	71	72				73	74	75	
	62	63	64	65				66	67	68	
	55	56	57	58				59	60	61	
	0	47	48	49	50	51	52	53	54		
	38	39	40	41	42	43	44	45	46		
	30	31	32	33	34	35	36	37			
	22	23	24	25	26	27	28	29			
		15	16	17	18	19	20	21			
				11	12	13	14				
				7	8	9	10				
				4	5	6					
				2	3						
					1						

Figure 2.1: Relative location of 3kmx3km MM5 grid cells for Lake Tahoe Basin
Note: Top of figure is northern side of Lake Tahoe.

Table 2.2: SNOTEL daily gage recorded annual maximum precipitation depths (inches/hr) for various durations

Gage	elevation	¹ begin	end	Year	1day	Year	7day	Year	30day
Echo Peak	7350	1-Jan-80	1-Jan-99	1983	9.10	1981	1.76	1990	0.29
Fallen Leaf	6300	1-Jan-79	1-Jan-99	1997	4.60	1980	1.97	1996	0.63
Glenbrook Creek	6360	1-Jan-48	1-Jan-01	1967	3.55	1967	1.22	1969	0.40
Hagan's Meadow	8000	1-Jan-78	1-Jan-99	1986	5.70	1986	1.84	1986	0.64
Heavenly Valley	8850	1-Jan-78	1-Jan-99	1994	6.50	1986	2.31	1986	0.71
Marlette Lake	8000	1-Jan-78	1-Jan-99	1997	9.50	1986	2.33	1986	0.76
Mt Rose Ski Area	8850	1-Jan-80	1-Jan-99	1986	10.90	1986	4.13	1986	1.21
Rubicon	7500	1-Jan-80	1-Jan-99	1997	6.20	1986	2.43	1986	0.96
Squaw Valley GC	8200	1-Jan-80	1-Jan-99	1997	8.30	1982	2.90	1986	1.26
Tahoe City Cross	6230	1-Jan-80	1-Jan-99	1997	4.60	1983	4.31	1983	1.01
Ward Creek	6750	1-Jan-78	1-Jan-99	1997	9.00	1986	4.11	1986	1.53

¹Period of record

Table 2.3: Distribution fit to MM5 precipitation annual maximums as measured by fraction error difference with top ranked annual maximum value¹

Distribution	1hour	1day	7day	30day
generalized logistic	0.137	0.017	0.336	0.1537
generalized extreme value	0.1388	0.0311	0.347	0.1738
generalized normal	0.1382	0.0408	0.3611	0.1855
Pearson III	0.1793	0.0683	0.4052	0.2135

¹Fractional difference = (top ranked precipitation – distribution quantile)/distribution quantile

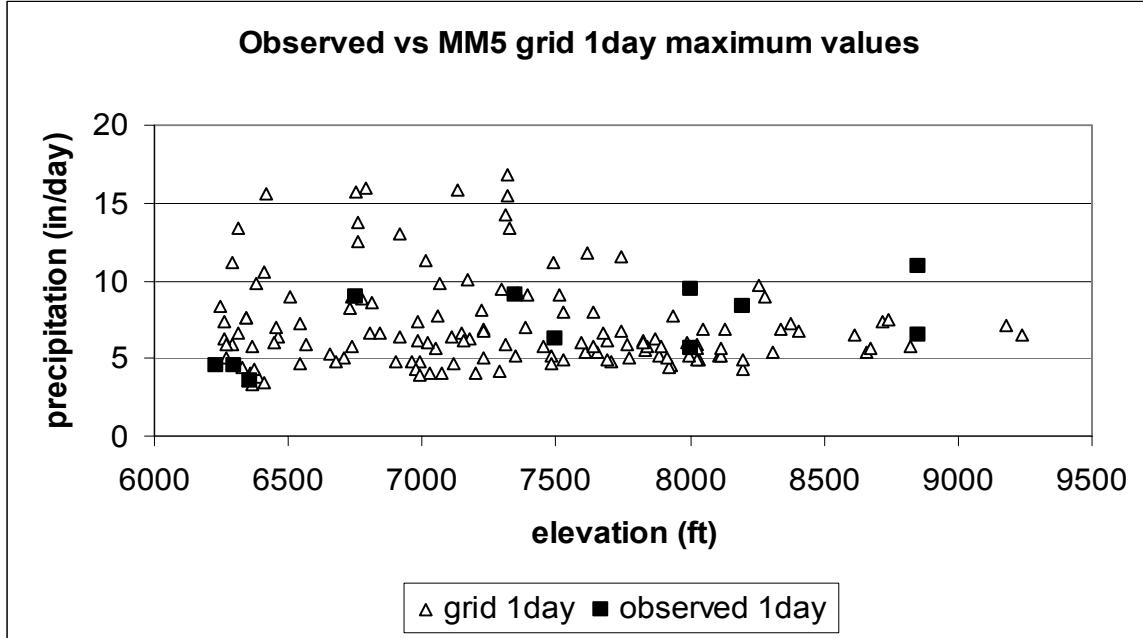


Figure 2.2: Comparison of period of record annual maximum values, MM5 grid simulated data and gage observations, 1day duration

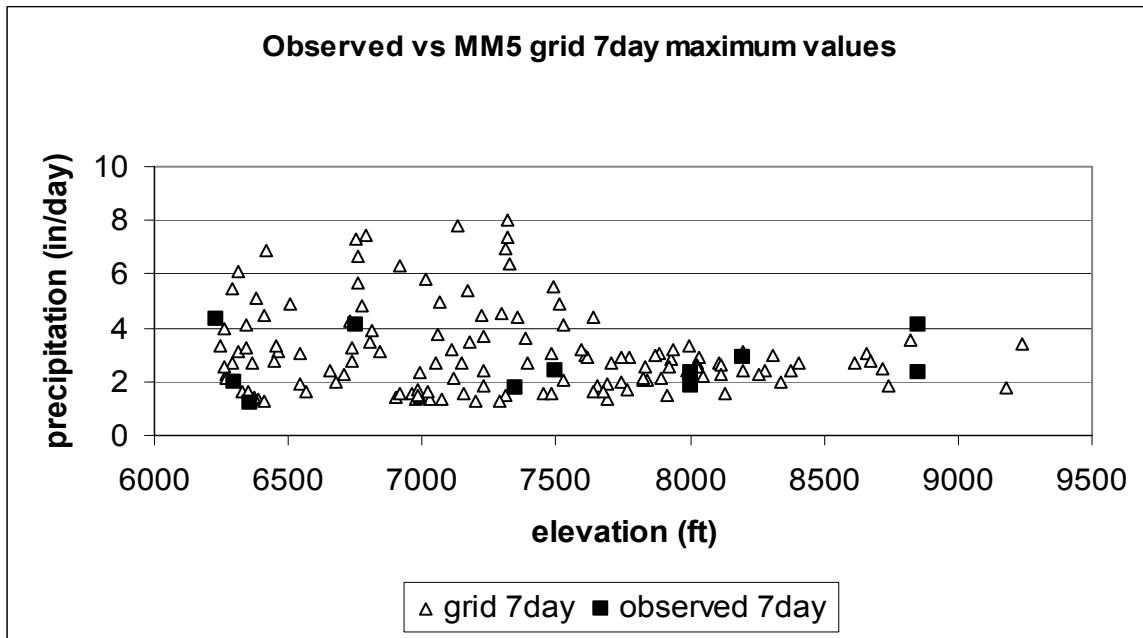


Figure 2.3: Comparison of period of record annual maximum values, MM5 grid simulated data and gage observations, 7day duration

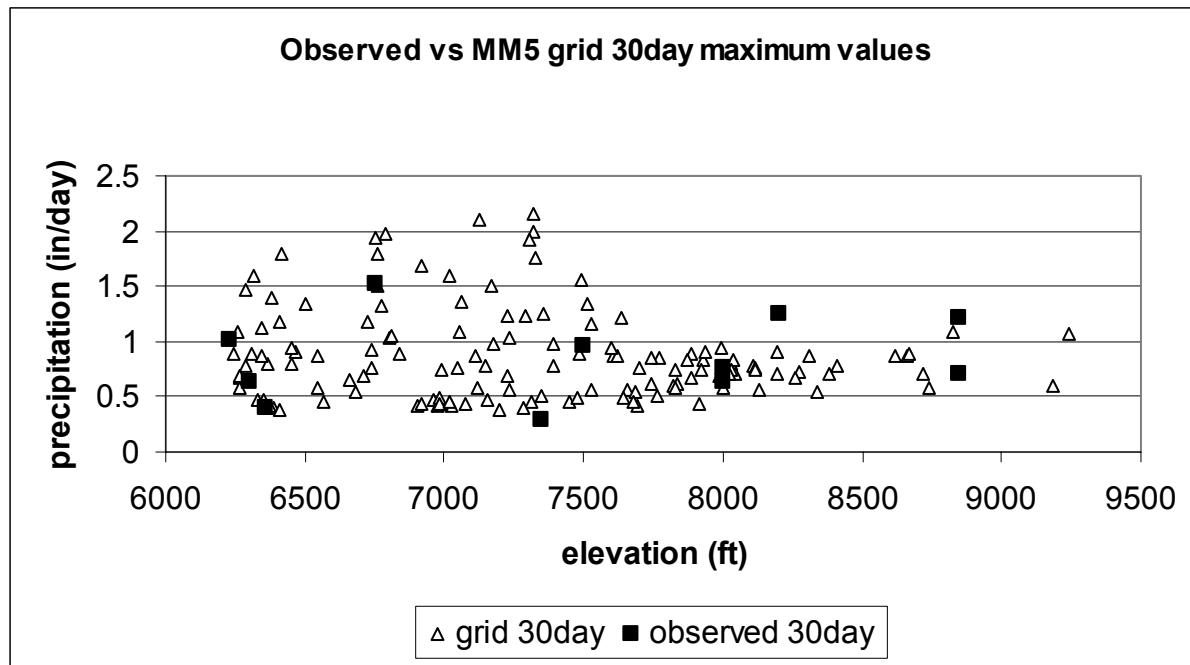


Figure 2.4: Comparison of period of record annual maximum values, MM5 grid simulated data and gage observations, 30day duration

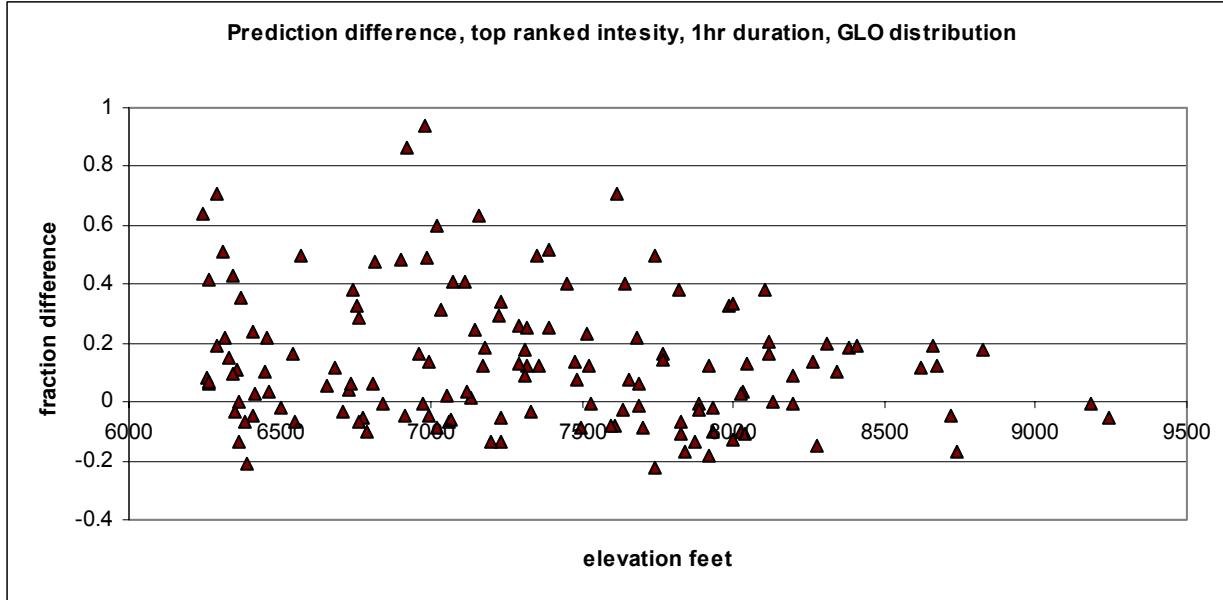


Figure 2.5: Prediction fraction difference, top ranked MM5 quantile minus GLO distribution estimate, 1hour duration, as a function of elevation for MM5 grids

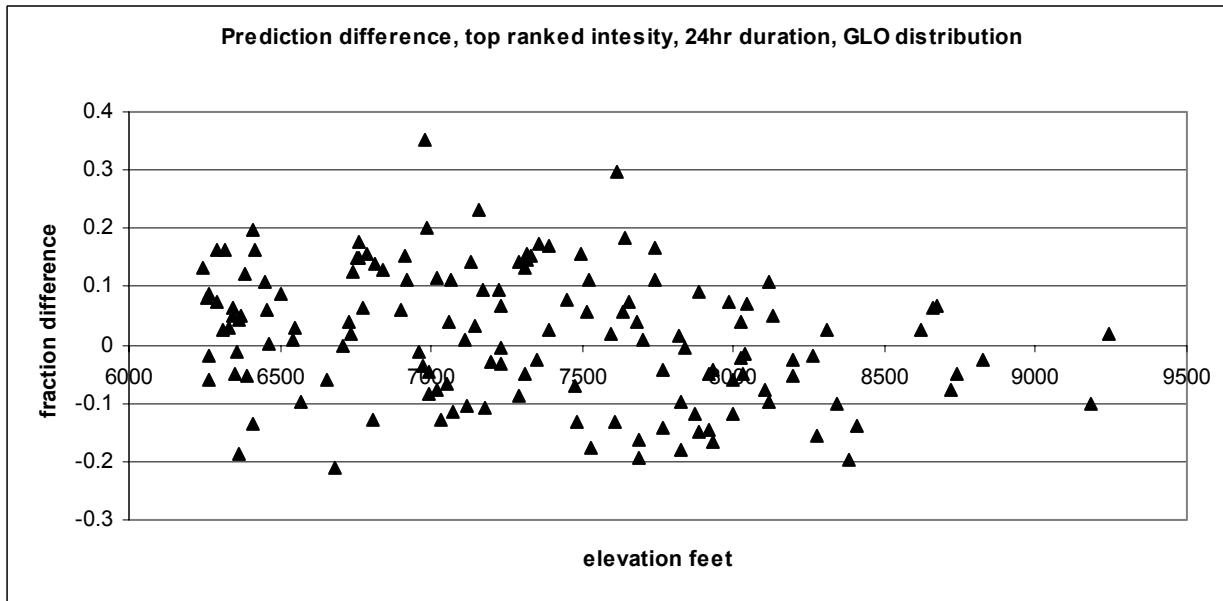


Figure 2.6: Prediction fraction error, top ranked MM5 quantile minus GLO distribution estimate, 24hour duration, as a function of elevation for MM5 grids

3. NOAA14 estimates

NOAA14 provides regional estimates of precipitation DDF relationships for the southwestern portion of the United States. The goal, obviously, was not to focus solely on Lake Tahoe.

Estimating the DDF relationships for Lake Tahoe was a problem in the NOAA14 study because of the lack of long duration precipitation records, particularly the total lack of hourly precipitation (personal communication Parzybok). For this reason, mean or median annual precipitation was estimated for the Lake Tahoe Basin using the PRISM model (Taylor et al., 1993). The DDF growth curves (see section 2.4.1, Hosking and Wallis 1997) were obtained based on a study of precipitation gage data from some region surrounding Lake Tahoe Basin. The estimates obtained from the NOAA14 website data server; consequently, result from the product of PRISM mapped mean or median values and the regional growth curve.

No precipitation depth-duration area reduction factors are available for the NOAA14 study. Consequently all comparisons are being made are for point NOAA14 estimates at grid cell centroids and MM5 grid cell average precipitation.

4. Comparison depth-duration-frequency estimates from MM5 simulated data and NOAA14

4.1. Comparisons for 50%, 10%, 1% exceedance frequency, 1hr, 24hr, and 7day durations

Comparison were made between the GLO distributions estimated from MM5 simulated precipitation and NOAA14 DDF estimates at selected MM5 grid cells at 50%, 10% and 1% exceedance probabilities for the 1hour, 24hour and 7day durations. The grid cells were selected to span a range of elevations and locations around the Lake Tahoe Basin. Tables 4.1 and 4.2, figures 4.1 and 4.2 provide example comparisons for the 1hour and 24 hour durations. Table 4.3 provides average differences in depth prediction. As can be see from the tables and figures, the distributions estimated from MM5 generally result in smaller precipitation depths than predicted by NOAA14 for 50% and 10% exceedance probabilities, but the opposite tends to be true for the 1% exceedance probability. The smallest difference occurs for the 1% chance, 1hour duration estimates. The difference increases with duration, and do not seem to be biased by location (east vs west or north vs south). The differences do not appear to be a function of elevation for shorter durations but do seem to increase somewhat with elevation for longer duration as can be seen from figures 4.3 and 4.4.

Table 4.1: Comparison of 1hour duration depth frequencies estimated from MM5 simulations and NOAA14 (inches)

MM5 Grid	150%		10%		1%	
	MM5	NOAA14	MM5	NOAA14	MM5	NOAA14
Grid2	0.32	0.63	0.63	0.87	1.36	1.55
Grid38	0.42	0.67	0.90	0.92	1.98	1.64
Grid41	0.26	0.55	0.51	0.77	1.10	1.42
Grid50	0.23	0.50	0.48	0.72	1.29	1.35
Grid 80	0.24	0.39	0.58	0.70	1.56	1.35
Grid 81	0.28	0.44	0.67	0.77	1.73	1.42
Grid 82	0.31	0.46	0.76	0.79	2.23	1.43
Grid83	0.41	0.70	0.68	0.97	1.08	1.76
Grid86	0.30	0.55	0.52	0.80	0.95	1.53
Grid 127	0.23	0.44	0.55	0.80	1.32	1.60
Grid 133	0.33	0.52	0.70	0.93	1.40	1.82
Grid 138	0.33	0.51	0.79	0.93	1.80	1.83

¹Exceedance frequency

Table 4.2: Comparison of 24hour duration depth frequencies estimated from MM5 simulations and NOAA14 (inches)

MM5 Grid	150%		10%		1%	
	MM5	NOAA14	MM5	NOAA14	MM5	NOAA14
Grid2	2.37	4.43	4.01	5.74	6.77	8.34
Grid38	2.91	5.08	5.54	6.55	11.68	10.46
Grid41	2.28	3.73	3.84	4.81	6.53	9.45
Grid50	1.83	3.14	3.34	4.03	6.26	6.96
Grid 80	1.26	1.92	2.38	3.12	4.50	5.83
Grid 81	1.48	2.40	2.79	3.84	5.14	4.80
Grid 82	1.67	2.64	3.37	4.32	6.76	6.00
Grid83	3.04	5.58	5.12	7.22	8.71	6.48
Grid86	2.51	3.28	4.93	4.23	10.15	6.13
Grid 127	1.33	2.40	3.02	4.08	7.30	6.24
Grid 133	1.57	3.36	3.57	5.52	8.88	8.64
Grid 138	1.68	3.36	3.77	5.76	9.12	8.88

¹Exceedance Frequency

Table 4.3: Average difference (inches) between estimated depths for duration and frequency at selected MM5 grids (e.g., see Table 4.1 and 4.2) and NOAA14 estimates

Duration	² 50%	10%	1%
1hour	-0.22	-0.18	-0.07
24hour	-1.45	-1.13	0.30
7day	-3.25	-3.51	3.92

¹Difference shown is (MM5-NOAA14) estimates (inches)

²Exceedance frequency

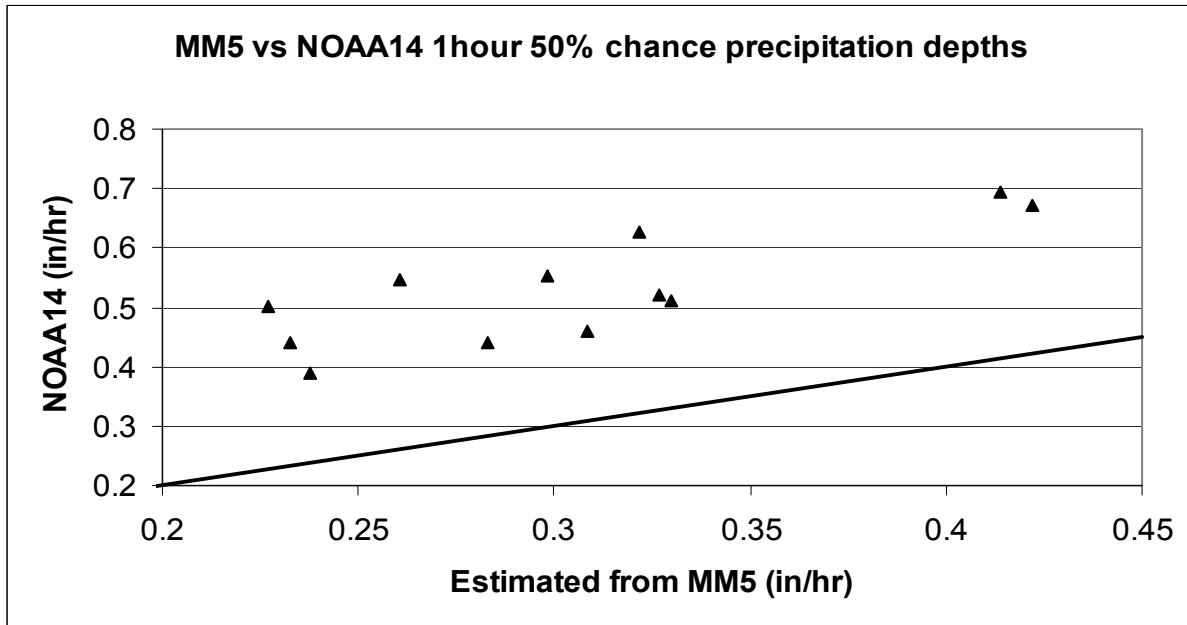


Figure 4.1: Comparison of precipitation 1hour 50% exceedance frequency estimated from MM5 simulations and NOAA14. Note: Line shows equal values

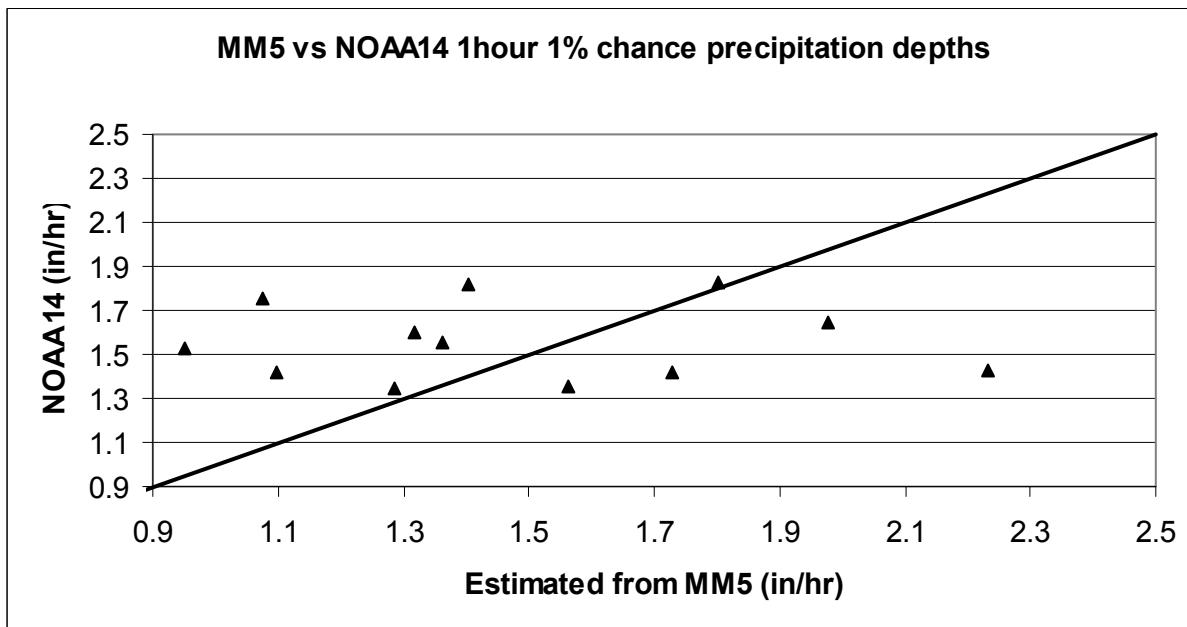


Figure 4.2: Comparison of precipitation 1hour 1% exceedance frequency estimated from MM5 simulations and NOAA14. Note: Line shows equal values

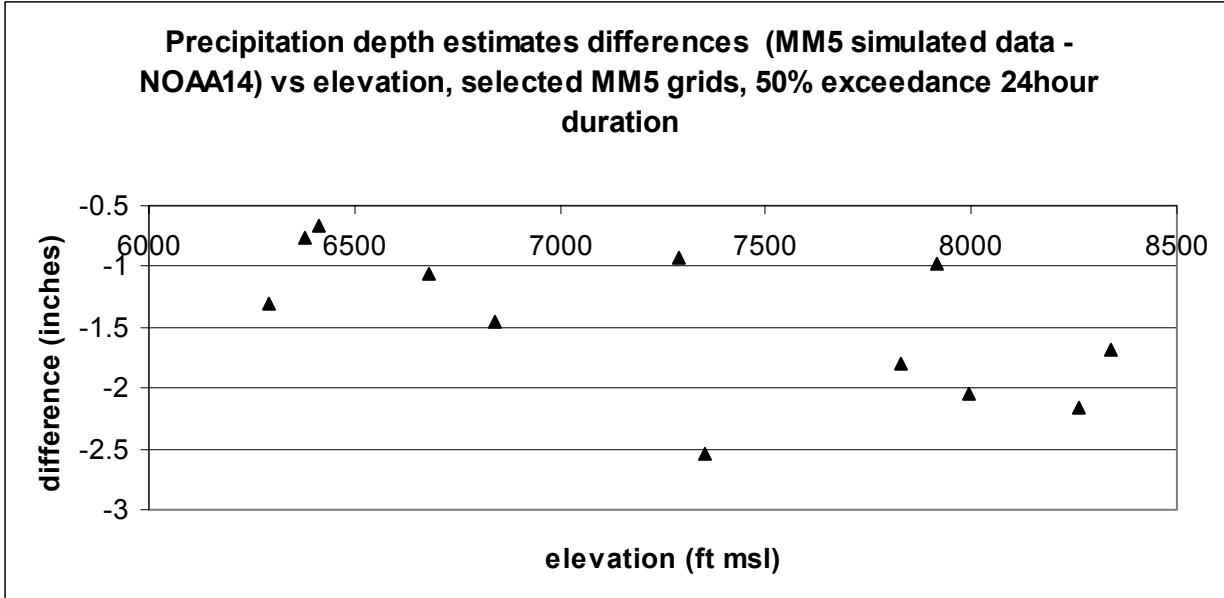


Figure 4.3: Precipitation depth estimation differences, from MM5 simulated data and NOAA14, 50% exceedance probability, 24hour duration

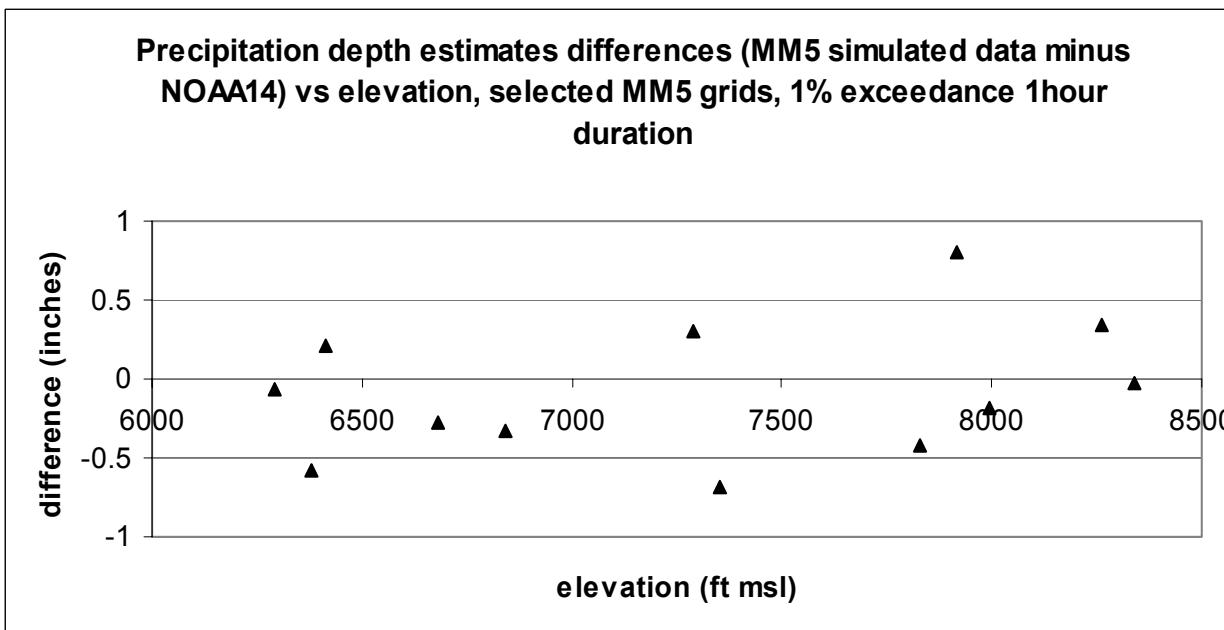


Figure 4.4: Precipitation depth estimation differences, from MM5 simulated data and NOAA14, 1% exceedance probability, 1hour duration

4.2. Comparison at current design precipitation, 2-year (50% chance) 6hour and 20year (5%) 1hour

The Storm Water Quality Investigations Committee (SWQIC) for Lake Tahoe requested that comparison be made for the regulatory volumes due to the 2-year (50% chance) 6hour duration and 20-year (5% chance) 1hour precipitation. As can be seen from Tables 4.4 and 4.5, the differences mimic the results in the previous section. Basically, for the shorter durations, NOAA14 results in higher precipitation volumes.

Table 4.4: 2-year (50%) 6hour comparison (inches)at selected grid cells

2year	MM5	NOAA14	Difference
grid80	0.710	1.020	-0.31
grid81	0.791	1.200	-0.41
grid82	0.857	1.260	-0.40
grid127	0.646	1.140	-0.49
grid133	0.790	1.500	-0.71
grid138	0.882	1.380	-0.50
		average	-0.47

Table4.5: 20-year (5%) 1hour comparison (inches) at selected grid cells

1hour	MM5	NOAA14	difference
80	0.798	0.866	-0.068
81	0.901	0.936	-0.035
82	1.067	0.956	0.110
127	0.729	0.997	-0.268
133	0.885	1.157	-0.272
138	1.037	1.157	-0.120
		average	-0.109

4.3. Comparisons with confidence intervals

Frequency distributions inferred from data are subject to statistical sampling error, i.e., errors resulting in the difference between the population and the estimates due to a limited sample size. A measure of this error is provided by confidence intervals. Confidence intervals can be interpreted as providing the likelihood that the population (no sampling error) value would lie in a particular interval.

A comparison was made between MM5 and NOAA14 confidence intervals to provide some rough measure of the likelihood that sampling error alone could explain the difference between estimates of precipitation frequency from these two sources. The measure is rough in that a more rigorous approach would be to perform a statistical hypothesis test to examine the difference between estimated frequency curves. However, this would require more information than is available from the NOAA14 study and is beyond the scope of this investigation.

As can be seen from Tables 4.6-4.8, the MM5 estimate lie outside the confidence limits provided for the NOAA14 estimates for selected exceedance probabilities , durations and grids in most cases. The same can be expected for other durations, exceedance probabilities and other grids. Application of hypothesis tests comparing estimated distributions by MM5 and NOAA14 would probably indicate that the differences between estimates in most cases are not due solely to sampling error.

Table 4.6: Comparison of MM5 estimates with NOAA14 estimate and 90% confidence bound, 50% chance, 1hour and 24hour (inches/hour)

Grid	¹ MM5	¹ NOAA14	² 5%	95%	MM5	NOAA14	5%	95%
80	0.24	0.39	0.46	0.35	0.05	0.08	0.08	0.07
81	0.28	0.44	0.51	0.39	0.06	0.10	0.11	0.09
82	0.31	0.46	0.52	0.41	0.07	0.11	0.12	0.10
127	0.23	0.44	0.52	0.39	0.06	0.10	0.12	0.09
133	0.33	0.52	0.60	0.45	0.07	0.14	0.16	0.12
138	0.33	0.51	0.60	0.45	0.16	0.24	0.27	0.21
number exceed limits				6				6

¹Approximately median estimate, ²Difference between 5% and 95% confidence limits gives equal interval 90% confidence interval

Table 4.7: Comparison of MM5 estimates with NOAA14 estimate and 90% confidence bound, 10% chance, 1hour and 24hour (inches/hour)

Grid	MM5	NOAA14	5%	95%	MM5	NOAA14	5%	95%
80	0.58	0.70	0.82	0.61	0.10	0.13	0.14	0.11
81	0.67	0.77	0.88	0.68	0.12	0.16	0.18	0.15
82	0.76	0.79	0.90	0.70	0.14	0.18	0.20	0.16
127	0.55	0.80	0.94	0.69	0.13	0.17	0.19	0.15
133	0.70	0.93	1.08	0.81	0.15	0.23	0.26	0.20
138	0.79	0.93	1.08	0.81	0.16	0.24	0.27	0.21
number exceed limits				5				6

¹Approximately median estimate, ²Difference between 5% and 95% confidence limits gives equal interval 90% confidence interval

Table 4.8: Comparison of MM5 estimates with NOAA14 estimate and 90% confidence bound, 1% chance, 1hour and 24hour (inches/hour)

Grid	MM5	NOAA14	5%	95%	MM5	NOAA14	5%	95%
80	1.56	1.35	1.60	1.06	0.19	0.20	0.22	0.17
81	1.73	1.42	1.68	1.13	0.21	0.25	0.28	0.22
82	2.23	1.43	1.69	1.15	0.28	0.27	0.31	0.24
127	1.32	1.60	1.92	1.25	0.30	0.26	0.30	0.23
133	1.40	1.82	2.19	1.43	0.37	0.36	0.41	0.31
138	1.80	1.83	2.19	1.43	0.38	0.37	0.43	0.32
number exceed limits				4				0

¹Approximately median estimate, ²Difference between 5% and 95% confidence limits gives equal interval 90% confidence interval

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Table 5.1: MM5 predicted grid cell (3kmx3km) average annual maximum precipitation depths (in/hr) for various durations, period of record, 1958-1999 (note: beginning date given at 24:00 hours, elevation, latitude and longitude at cell centroid) (continued)

MM5	date	1hour	date	1day	date	7day	date	30day	elevation	lat	long
GRID101	1-Sep-72	0.9274	16-Feb-86	0.1489	11-Feb-86	0.0694	11-Feb-86	0.0197	6349	39.1388	-119.9642
GRID102	1-Sep-72	1.5004	1-Sep-72	0.166	11-Feb-86	0.0594	11-Feb-86	0.018	6990	39.1388	-119.9284
GRID103	1-Sep-72	2.1411	31-Aug-72	0.2423	11-Feb-86	0.0672	11-Feb-86	0.0206	7640	39.1388	-119.8926
GRID104	14-Sep-99	1.6059	16-Feb-86	0.6602	11-Feb-86	0.3242	11-Feb-86	0.0875	7129	39.1664	-120.2149
GRID105	14-Sep-99	1.1243	16-Feb-86	0.6658	11-Feb-86	0.3117	11-Feb-86	0.0822	6787	39.1664	-120.1791
GRID106	7-Jun-98	1.0354	16-Feb-86	0.648	11-Feb-86	0.2871	11-Feb-86	0.0745	6419	39.1665	-120.1433
GRID107	9-Sep-75	2.2453	9-Sep-75	0.2565	11-Feb-86	0.0707	11-Feb-86	0.0207	6984	39.1666	-119.9284
GRID108	9-Sep-75	2.0447	9-Sep-75	0.2136	11-Feb-86	0.0819	11-Feb-86	0.0243	7998	39.1665	-119.8925
GRID109	7-Jun-98	0.903	16-Feb-86	0.5443	11-Feb-86	0.264	11-Feb-86	0.0704	6915	39.1942	-120.1792
GRID110	7-Jun-98	0.8331	16-Feb-86	0.5228	11-Feb-86	0.2377	11-Feb-86	0.0627	6762	39.1943	-120.1433
GRID111	9-Sep-75	1.6748	16-Feb-86	0.441	11-Feb-86	0.1874	11-Feb-86	0.0492	6411	39.1943	-120.1075
GRID112	9-Sep-75	2.5462	16-Feb-86	0.3463	11-Feb-86	0.1402	11-Feb-86	0.037	6245	39.1943	-120.0717
GRID113	9-Sep-75	2.9773	9-Sep-75	0.3082	11-Feb-86	0.0634	11-Feb-86	0.0181	6981	39.1943	-119.9283
GRID114	9-Sep-75	1.7391	9-Sep-75	0.2564	11-Feb-86	0.0867	11-Feb-86	0.0251	7822	39.1943	-119.8925
GRID115	9-Sep-75	0.7567	16-Feb-86	0.4114	11-Feb-86	0.2083	11-Feb-86	0.0563	7063	39.2220	-120.1792
GRID116	9-Sep-75	1.1248	16-Feb-86	0.3917	11-Feb-86	0.1893	11-Feb-86	0.051	7293	39.2220	-120.1434
GRID117	9-Sep-75	2.1527	16-Feb-86	0.3559	11-Feb-86	0.1629	11-Feb-86	0.0436	6813	39.2221	-120.1075
GRID118	9-Sep-75	2.3732	16-Feb-86	0.3145	11-Feb-86	0.1362	11-Feb-86	0.036	6345	39.2221	-120.0717
GRID119	9-Sep-75	1.0897	16-Feb-86	0.2619	11-Feb-86	0.1071	11-Feb-86	0.0285	6262	39.2221	-120.0359
GRID120	9-Sep-75	1.8366	8-Sep-75	0.2473	11-Feb-86	0.0896	11-Feb-86	0.0238	6268	39.2221	-120.0000
GRID121	9-Sep-75	2.634	8-Sep-75	0.266	11-Feb-86	0.0643	11-Feb-86	0.018	6917	39.2221	-119.9283
GRID122	9-Sep-75	1.685	16-Feb-86	0.2136	11-Feb-86	0.0743	11-Feb-86	0.021	7350	39.2221	-119.8925
GRID123	9-Sep-75	1.6624	16-Feb-86	0.2928	11-Feb-86	0.1496	11-Feb-86	0.0408	7388	39.2498	-120.1435
GRID124	9-Sep-75	2.117	16-Feb-86	0.2662	11-Feb-86	0.1335	11-Feb-86	0.0363	7112	39.2498	-120.1076
GRID125	9-Sep-75	1.4018	16-Feb-86	0.241	11-Feb-86	0.1164	11-Feb-86	0.0315	6736	39.2499	-120.0717
GRID126	9-Sep-75	1.1895	16-Feb-86	0.2201	11-Feb-86	0.1013	11-Feb-86	0.0272	6657	39.2499	-120.0359
GRID127	9-Sep-75	1.2267	22-Sep-90	0.1992	11-Feb-86	0.0842	11-Feb-86	0.0228	6680	39.2499	-120.0000
GRID128	9-Sep-75	1.9274	22-Sep-90	0.2478	11-Feb-86	0.0667	11-Feb-86	0.0186	6567	39.2499	-119.9641
GRID129	9-Sep-75	2.2196	8-Sep-75	0.2483	11-Feb-86	0.0671	11-Feb-86	0.0189	7019	39.2499	-119.9283
GRID130	9-Sep-75	1.2286	9-Mar-95	0.1669	11-Feb-86	0.0575	11-Feb-86	0.0178	7074	39.2498	-119.8924
GRID131	9-Sep-75	1.2804	9-Sep-75	0.1922	11-Feb-86	0.088	11-Feb-86	0.0243	7120	39.2776	-120.0718
GRID132	10-Sep-75	1.098	9-Sep-75	0.2028	11-Feb-86	0.0854	11-Feb-86	0.0234	7529	39.2777	-120.0359
GRID133	23-Sep-90	1.1575	22-Sep-90	0.2496	11-Feb-86	0.0893	21-Jan-86	0.0245	7827	39.2777	-120.0000
GRID134	9-Sep-75	1.4825	10-Sep-76	0.2552	11-Feb-86	0.0811	11-Feb-86	0.0228	7688	39.2777	-119.9641
GRID135	9-Sep-75	1.6604	10-Sep-76	0.2441	11-Feb-86	0.0713	11-Feb-86	0.0209	7767	39.2776	-119.9282
GRID136	9-Sep-75	0.964	9-Mar-95	0.1943	11-Feb-86	0.0652	11-Feb-86	0.0206	7479	39.2776	-119.8924
GRID137	10-Sep-75	1.8273	9-Sep-75	0.2785	11-Feb-86	0.0684	11-Feb-86	0.0189	7679	39.3055	-120.0359
GRID138	10-Sep-75	1.6835	9-Sep-75	0.2838	11-Feb-86	0.0815	21-Jan-86	0.0228	8340	39.3055	-120.0000
GRID139	10-Sep-75	1.569	10-Sep-76	0.3075	11-Feb-86	0.1036	21-Jan-86	0.0296	8721	39.3055	-119.9641
GRID140	10-Sep-75	1.4163	10-Sep-76	0.3123	11-Feb-86	0.0754	11-Feb-86	0.0242	8739	39.3054	-119.9282
GRID141	3-Jun-89	1.1648	9-Mar-95	0.2849	11-Feb-86	0.0647	11-Feb-86	0.0231	8132	39.3054	-119.8923
GRID142	10-Sep-75	1.9884	10-Sep-76	0.2953	11-Feb-86	0.074	11-Feb-86	0.0246	9182	39.3332	-119.9282

Table 5.2: SNOTEL daily gage recorded annual maximum precipitation depths for various durations

Gage	elevation	¹ begin	end	Year	1day	Year	7day	Year	30day
Echo Peak	7350	1-Jan-80	1-Jan-99	1983	9.10	1981	1.76	1990	0.29
Fallen Leaf	6300	1-Jan-79	1-Jan-99	1997	4.60	1980	1.97	1996	0.63
Glenbrook Creek	6360	1-Jan-48	1-Jan-01	1967	3.55	1967	1.22	1969	0.40
Hagan's Meadow	8000	1-Jan-78	1-Jan-99	1986	5.70	1986	1.84	1986	0.64
Heavenly Valley	8850	1-Jan-78	1-Jan-99	1994	6.50	1986	2.31	1986	0.71
Marlette Lake	8000	1-Jan-78	1-Jan-99	1997	9.50	1986	2.33	1986	0.76
Mt Rose Ski Area	8850	1-Jan-80	1-Jan-99	1986	10.90	1986	4.13	1986	1.21
Rubicon	7500	1-Jan-80	1-Jan-99	1997	6.20	1986	2.43	1986	0.96
Squaw Valley GC	8200	1-Jan-80	1-Jan-99	1997	8.30	1982	2.90	1986	1.26
Tahoe City Cross	6230	1-Jan-80	1-Jan-99	1997	4.60	1983	4.31	1983	1.01
Ward Creek	6750	1-Jan-78	1-Jan-99	1997	9.00	1986	4.11	1986	1.53

¹Period of record

6. Appendix figures

